Numerical modelling of tight knots

PhD or Post-doc, 2020

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Hosting Laboratory: ELAN team (INRIA and LJK, Grenoble), `https://team.inria.fr/elan/`

Practical details: PhD thesis (3 years) or post-doctoral position (1 year renewable), salary as defined in Inria scales. Start in fall 2020.

Context: Knots are fascinating and widely spread structures which combine the seeming simplicity of a thread with some intricate topology to obtain many different properties. As such, they have been mathematically studied since the 18^{th} century and *knot theory* closely developed along the early foundations of mathematical topology until the modern use of algebraic topology, which eventually allowed to classify knots using simple polynomial functions. However, while the geometry of knots is now well understood, their mechanical properties is still vague and the choice of a particular knot for some task is most of the time governed by empiricism. From the numerical perspective, some recent works have focused on reduced models for the simulation of threads [1, 8, 9, 2], thereby efficiently accounting for the nonlinear behaviour of this slender structures. However, the challenging case of tight and self-locking knots, where both the knot topology and the thread mechanical behaviour come into play, have been poorly studied despite their intensive and crucial use in many fields such as surgery or rock-climbing, or their appearance in many biological phenomena [5].

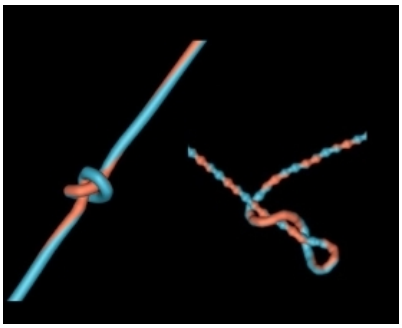

Figure 1: Knot simulation with frictional contact and thin – Kirchhoff – rods, taken from [3].

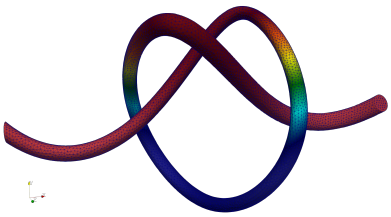

Figure 2: Full 3D finite-element model of an overhand knot [7].

Objectives: The goal of the project is to develop numerical models for the study of tight knots. To this end, various approaches will be considered, ranging from full ab-initio finite-element models to reduced physical models, and the numerical aspects will be built upon tools developed by researchers from the ELAN team [6, 4, 7]. The project will also involve collaborations with physicists to develop and validate the model.

Required Skills: For a post-doc, candidates must hold a PhD in any field among computing science / physics / mechanical engineering / applied mathematics, and candidates should have a proven research track record, demonstrated by publications in peer-reviewed journals in one or more of the above areas. For all candidates, good skills in numerical analysis (modelling, numerical discretisation of ODEs and PDEs, finite elements, optimisation) as well as

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in algorithmics and programmation (C/C++, Python) are required. Curiosity and taste for applications in mechanics, physics and computer graphics would be appreciated.

How to apply Candidates should apply **before July 15, 2020** by sending an e-mail to Thibaut.Metivet@inria.fr, Florence.Descoubes@inria.fr, and Melina.Skouras@inria.fr. Applications will be examined progressively as they are received. The application should contain:

- For a PhD:
  - a cover letter outlining the motivation of the applicant
  - the list of the classes followed during master (M1 and M2) and the grades obtained
  - a detailed CV of the applicant, including (possibly) the publication list, scientific and computing skills, and interests.
  - one or several reference letters (from a professor, an internship advisor, etc.)
  - any other document that the applicant would like to bring attention to in her/his application.
- For a post-doc:
  - a cover letter outlining the motivation of the applicant
  - a copy of the PhD diploma, together with reviewing and defense reports
  - a detailed CV of the applicant, including the publication list, scientific and computing skills, and interests.
  - one or several reference letters provided (at least) by the PhD advisor(s), possibly also by an academic or industrial partner, or a scientific personality
  - any other document that the applicant would like to bring attention to in her/his application.

Keywords: Numerical modelling, analysis and simulation, mechanics of thin elastic rods, dry frictional contact, physics of knots.

References

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